Activity Report 2015 - JLAB12

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1 Introduction

The Frascati JLAB12 group participates into the physics program carried on by the CLAS collaboration in the Hall B of the Jefferson Laboratory (JLab). The physics program of the group is focused on the precision study of the three-dimensional structure of the nucleon and its internal dynamics. This is achieved through the determination of three-dimensional parton distribution functions: the Transverse Momentum Dependent parton distribution (TMD), the Generalized Parton Distribution (GPD) and the Fracture functions.

The TMDs describe the quarks and gluons inside the nucleon in the 3D momentum space and are accessible in Semi-Inclusive Deep Inelastic Scattering (SIDIS) measurements in the current fragmentation region. In the collinear limit, they reduce to the ordinary Parton Distribution Functions (PDF). The GPDs describe longitudinal momentum distributions at a given transverse spatial point and are measured in exclusive reactions. The Fracture Functions describe the conditional probability to produce a given hadron when a hard photon hits a quark inside the nucleon and are measured in SIDIS processes in the target fragmentation region. The structure functions containing these functions enter in the Fourier components of the cross section of the process and they are accessed through the measurement of single or double spin asymmetries.

The group is also involved in the construction of a Ring Imagning CHerenkov (RICH) detector to improve the particle identificaton (PID) capabilities of the CLAS12 detector which is now under installation in the Hall B of the JLab.

2 Data analysis activity

2.1 GPD measurements

The simplest way to access the GPDs is to study the Deeply Virtual Compton Scattering (DVCS) exclusive process, in which a hard photon is produced in the final state. The Fourier coefficients of the cross section can be written in terms of the so-called Compton Form Factors (CFF), particular combinations of GPDs. By measuring cross section asymmetries, it is possible to extract from the data these CFF.

In 2014, the measurements of the Single Beam and Target Spin Asymmetries (BSA and TSA) and of the Double Spin Asymmetries (DSA) using the 5.5 GeV polarized electron beam and a ammonia longitudinally polarized target have been completed under the responsability of S. Pisano and A. Biselli and the results published [1].

2.2 Fracture Function measurements

The measurement of the polarization of the Λ in SIDIS electroproduction has been carried out by J. Phillips for his PhD Thesis at the Glasgow University under the supervision of M. Mirazita. The analysis showed that the Λ polarization is small, compatible with zero within the error bars, when the hadron is produced at forward angles. On the contrary, it becomes larger, of the order of 20%, at backward angles, when the data are essentially in the target fragmentation region, i.e. when the recoil hadron is produced from the fragmentation of the target remnant. In this regime, the polarization transfer from the electron beam to the recoil Λ is directly propotional to the Fracture Function ΔM^L.

The defense of the thesis by J. Phillips has been done in november.

2.3 PDF measurements

An interesting way to access the TMDs is provided by the DiHadron SIDIS processes (DiSIDIS), in which two mesons (for example two pions) are produced forward in the final state. In this case, the cross section takes a simple form of a product of a TMD and a DiHadron Fragmentation Function (DiFF). In the collinear limit, where the transverse momenta of the hadrons are integrated out, the DiSIDIS allows the access to the higher-twist PDF e, g_T and h_L, that, together with the leading twist unpolarized f_1, helicity g_1 and transversity h_1, complete the collinear description of the nucleon structure up to *twist-3*. Measurement of DiSIDIS asymmetries with a charged pion pair on an unpolarized proton target has been completed by S. Pisano and is now in the final stage of the review by the CLAS Collaboration. A similar analysis with one neutral and one charged pion has been started by A. Biselli.

A review paper on the physics of the DiSIDIS process has been published with S. Pisano as co-author [2].

2.4 TMD measurements

In a complementary way to the previous two hadron measurements, one can study the case in which the two pions are produced back-to-back. The forward pion comes from the fragmentation of the struck quark, while the backward one is produced in the fragmentation of the target remnant. Thus, the cross section can be written as the convolution of a transverse momentum dependent fragmentation function and a transverse momentum dependent Fracture Functions. It can be shown that in this particular regime a BSA arises at leading twist, contrary to all other SIDIS processes studied till now in which the BSA is a higher twist effect. In addition, the theory predicts a linear dependence of the BSA from the product of the transverse momenta of the two pions. The analysis of this process has been started by S. Pisano and the preliminary results are in agreement with the theoretical expectations.

3 Proposals of 12 GeV experiments

A new proposal [3] for measurements of the Deeply Virtual Compton Scattering on the neutron with a longitudinally polarized deuterium target has been presented to the JLab Program Advisory Committee (PAC), with S. Pisano as cospokeperson. The aim of the proposal is to measure the GPD H_n so that, together with the approved experiments with unpolarized and longitudinally polarized proton target and with unpolarized deuterium, a complete extraction of the GPDs on the proton and on the nucleon could be obtained. The proposal has been conditinally approved and must come back to the next PAC in order to be better integrated in the scheduled first five year data taking of CLAS12.

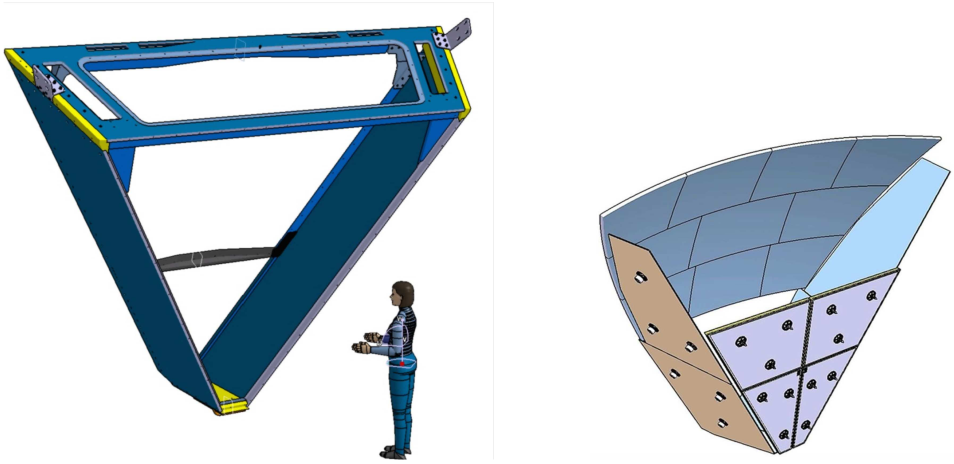

Figure 1: *The RICH box (left plot) and the mirror system (righ plot).*

4 The RICH of CLAS12

The construction of a RICH detector to improve the PID capabilities of the CLAS12 spectrometer of the Hall B at JLab is in progress under the lead of INFN physicists. The goal of the detector is to achieve a pion/kaon separation at the level of 1:500 in the momentum range between 3 and 8 GeV/c.

The detector is composed by an aerogel radiator, an array of multianode photomultiplier tubes (MAPMTs) for the Cherenkov light detection and a mirror system to direct the large angle photons onto the photodetectors. All these elements are contained in a large trapezoidal box, of approximate height of 3.5 m and large base of about 4 m. Test measurements at the T9 experimental hall of CERN using a hadron beam and a small scale RICH prototype have shown that the required performances can be obtained with this design of the detector. The final results of these tests in the case when the Cherenkov photons are detected without any reflection on the mirrors have been recently published [4].

The LNF is responsible for the design and construction of the RICH box. It is made by structural elements (two lateral panel, the lower base and the two upper angular blocks) in aluminum and a number of other elements (frontal and back panels, top panel, reinforcement ribs) in carbon fiber. A schematic drawing of the RICH box is shown in the left plot of Fig. 1. In 2015, the tender for this construction has been assigned to the *Tecnologie Avanzate srl* company (Veroli, Italy) and the construction is started.

Other activities carried out under the responsibility of the LNF group are the following.

- The test for the cooling system of the front end electronics

  The readout electronics, based on the MAROC3 chip, is mounted directly on the back of the MAPMTs and must be refrigerated in order to prevent damage of the detectors downstream to the RICH. Tests have been performed at LNF with a prototype of half of the system and the results showed that the temperature can be effectively controlled by flushing fresh air. The final design of the cooling system is now under development.

- Tests on the mirrors

  A scheme of the RICH mirror system is shown in the right plot of Fig. 1. Several prototypes of the mirrors have been tested at LNF with satisfactory results. Thus, in 2015 the construction of the spherical mirror in carbon fiber has been assigned to the *Composite Mirror Application Inc.* company (Tucson, USA), while the construction of the planr mirror in glass has been assigned to the *Media Lario srl* company (Bosisio Parini, Italy). The first mirros are expected to be delivered to JLab in 2016.

- Mirror supporting elements

  The mirrors are installed by means of a three point scheme that allows their alignment. Some prototype of the mirror supports have been produced by the LNF workshop using the rapid prototyping machine. The optimization of the design and materials is in progress by using a small scale test bench also produced by the LNF workshop (Fig. 2, left plot).

- Production of the aerogel

  The production of the aerogel has been assigned to the Budker Institute for Nuclear Physics (BINP) in 2014 and the first tiles have been delivered to JLab in 2015. All the tiles complied with the technical specifications.

- Test of the aerogel supporting system

  The aerogel tiles are mounted on top of the frontal planar mirrors and are kept in place through a net of thin wires attached to the mirror frame (Fig. 2, right plot). The design of the system and the position of the wires is currently under study by using the first prototype of one of the planar mirrors.

The RICH has been reviewed in October 2015 by a committee composed by JLab physicists with observers from the USA Department of Energy. During the review, all the technical and management aspects have been scrutinized and the construction milestones have been revised in view of the progress of the project. The current schedule foresees the installation of the RICH inside the CLAS12 by the end of the summer 2017, on time for the beginning of the data taking.

5 List of Conference Talks by LNF Authors in Year 2015

1. S. Pisano - *GPDs in experiments*, invited talk at the First Italian Workshop on Hadron Physics and Non-Perturbative QCD - NPQCD2015, Cortona, Italy, 20-22 April 2015.

2. M. Mirazita - *Lambda production in the DIS target-fragmentation region: the CLAS12 program*, invited talk at the International Workshop TMDe2015: A path towards TMD extraction, Trieste, Italy, 2-4 September 2015.

3. S. Pisano -*Orbital Angular Momentum Measurements from DVCS at JLab*, invited talk at the Light Cone 2015 - LC2015, Laboratori Nazionali di Frascati, Frascati, Italy 21-25 September 2015.

4. P. Rossi -*Jefferson Lab: Present and Future*, invited talk at the Light Cone 2015 - LC2015, Laboratori Nazionali di Frascati, Frascati, Italy 21-25 September 2015.

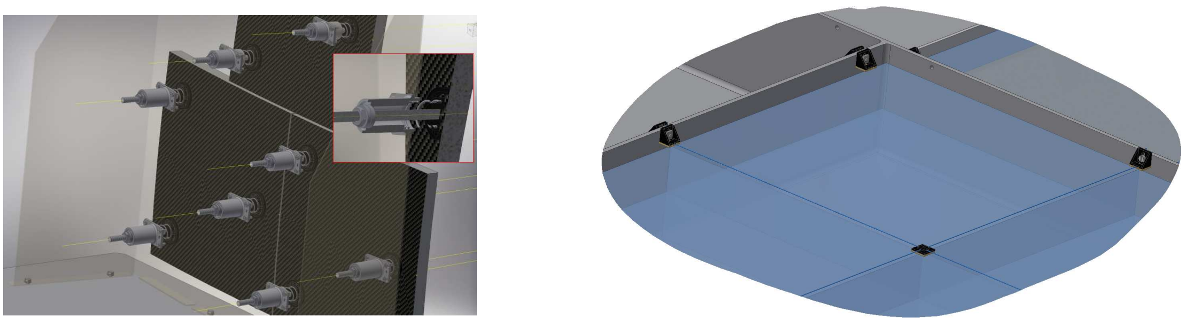

Figure 2: *The prototype to study the mirror mounting tools (left plot) and the scheme for the aerogel tile installation on the planar mirror (righ plot).*

5. S. Pisano - *Studies of nucleon GPD properties at JLab*, invited talk at the 10th Circum-Pan-Pacific Spin Symposium on High Energy Spin Physic - PacSpin2015, Taipei, Taiwan, 5-8 October 2015.

6. P. Rossi -*JLab12: Status of the Upgrade*, invited talk at the DNP 2015: APS Division of Nuclear Physics - Santa Fe' (USA), 28-31 October 2015.

6 Publications

References

1. A. Biselli, S. Pisano *et al.*, (CLAS Collaboration), Longitudinal target-spin asymmetries for deeply virtual Compton scattering - Phys. Rev. Lett. **114** (2015) 3, 032001 and Phys.Rev.Lett. **114** (2015) 8, 089901.
   S. Pisano, A. Biselli *et al.*, (CLAS Collaboration), Single and double spin asymmetries for deeply virtual Compton scattering measured with CLAS and a longitudinally polarized proton target - arXiv:1501.07052 and Physical Review **D91** (2015) 5, 052014.

2. S. Pisano and M. Radici, Di-hadron fragmentation and mapping of the nucleon structure - arXiv:1511.03220, to be published on EPJA.

3. Deeply virtual Compton scattering on the neutron with a longitudinally polarized deuteron target - https://www.jlab.org/exp_prog/proposals/15/PR12-15-004.pdf

4. S. Anefalos Pereira *et al.*, Test of the CLAS12 RICH large-scale prototype in the direct proximity focusing configuration - Eur. Phys. J. **A52** (2016) 2, 23.